

## PROCESS AND DEVICE FOR VASCULAR NAVIGATION

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims a benefit of a priority under 35 USC 119(a)-(d) to French Patent Application No. 02 16286 filed December 20, 2002, the entire contents of which are hereby incorporated by reference.

### BACKGROUND OF THE INVENTION

[0002] This invention relates to a process and device for vascular navigation intended for a radiological imaging device and more particular to an X-ray fluoroscopy device.

[0003] Process for vascular navigation enable a map to be drawn up of the blood vessels of an area of interest of a patient faced with surgery. During vascular surgery the surgeon inserts devices and tools (guide, catheter, stents, etc) into the blood vessels and moves them to where the lesion needs to be treated. For this the surgeon uses the previously created map of the vessels as a guide by injecting contrast products into the vessels to be X-rayed and by simultaneous acquisition of a sequence of images showing progressive opacification of the vessels, as illustrated in Figure 1. The entire sequence is then treated by well-known image treatment techniques, such as the maximum opacification technique. The drawback to this technique is that the vascular map always contains the bones and soft tissue (forming said background structures) that can more or less hide parts of the blood vessels on account of their possible high absorption of X-rays. In the event where this particular map is subtracted from a fluoroscopic image taken during the intervention, the vessels and background structures are treated in the same manner, and the operator or medical practitioner may be uncertain of the route to follow by these instruments, or of their position. This is prejudicial for patients due to error causes this may contribute and by prolonging operating times.

**BRIEF DESCRIPTION OF THE INVENTION**

**[0004]** An embodiment of the invention is to provide a process and device for vascular navigation that may resolve the abovementioned problems. An embodiment of the invention and equivalents provides a process and a device for vascular navigation intended for a radiography/fluoroscopy device. The device may comprise means for emitting radiation, such as a source of X-rays; means for recording or acquiring an image arranged opposite the source and means for support arranged between the source and the means for recording on which a patient with an area or region of interest to be imaged is intended to be placed. The process comprises: acquiring a series of successive images of the region of interest by the means for recording; determining from the series of images thus acquired a first mask presenting background structures and blood vessels of a region of interest; presenting a second mask of only the background structure; acquiring an image exhibiting at least one instrument introduced into one of the vessels in the region of interest, determining an image for visualizing by combining the first and second masks and the image; and displaying the image to be visualized thus determined on means for display.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**[0005]** An embodiment of the invention will be better understood from the following description when read together with the attached drawings, in which:

**[0006]** Figure 1 is a series of images acquired when a contrast product is injected, serving as input data in an embodiment of the process;

**[0007]** Figure 2 is a diagram illustrating a first mask in an embodiment of the process;

**[0008]** Figure 3 is a diagram illustrating a second mask in an embodiment of the process;

**[0009]** Figure 4 is a diagram illustrating an image to be visualized in an embodiment of the process;

[0010] Figure 5 is a diagram illustrating noise correction on images of an embodiment of the process; and

[0011] Figure 6 is a diagram of a radiography device suitable for implementing an embodiment of the process.

#### DETAILED DESCRIPTION OF THE INVENTION

[0012] Figure 6 shows an embodiment of a radiography device 100. The device comprises means for recording or acquiring images, such as X-ray plates 102, and means for emitting radiation 103 in the form of a source of X-rays. The means for recording or acquiring images 102 can be a flat probe or a brightness amplifier linked to a camera. The means for emitting radiation 103 and the means for recording or acquiring images 102 are fixed at each end of a carry arm 107 serving as balance counter, here resembling a semi-circle. The semi-circular arm 107 is slidably attached to a second arm 108. Second arm 108 is in turn rotatably attached to a base 109 of the device 100. Base 109 is mounted to rotate 112 relative to the ground.

[0013] Arm 108 is essentially suitable for carrying out movements of rotation 106 about its own axis. The semi-circular arm 107 is suitable to slide relative to the arm 108, such that the semi-circular arm 107 describes a movement of rotation relative to the center of the semi-circle forming the arm 107.

[0014] In use a body, such as a patient 200, is placed on a support (not shown) between the source 103 and the means for recording or acquiring images 102, so that a region of interest 104 of the patient 200 is located in a field 110 of the apparatus.

[0015] In Figure 1 a first stage of the process for aiding navigation is the acquisition of a series of successive images  $I_n$  of the region of interest 104 of the patient 200, whereas a contrast product has been injected into the blood vessels of the region of interest. In Figure 1 illustrates a set of five successive images, numbered I0 to I4, showing the progression of the contrast product in the circulatory system 20 of the region of interest under the action of the blood circulation of the patient 200. In

addition, the different images of the sequence presenting a set of so-called background structures 10 which correspond to all the tissue of the region of interest of the patient 200 other than the blood vessels. In Figure 1 of the set of so-called background structures only the bones 10 have been shown.

[0016] A second stage the process of aiding navigation determines a first mask PO and a second mask M. The second stage can be taken simultaneously with acquiring the series of successive images previously described. In this case the series of images is not recorded in means for image storage of the device. Only the first and second masks are recorded in the means for storage.

[0017] In Figure 2 the first mask PO is determined according to the maximum opacification 1. In the first instance the first mask PO is initialized with the content of the first image  $I_0$  of the sequence of images previously acquired. Next, each point (i, j) of the image  $I_n$  is compared to the corresponding point (i, j) of the first mask PO by looping on the set of other  $I_n$  images of the image sequence. If the intensity of the point in question of the  $I_n$  image is less than that of its equivalent on the mask PO, then the point of the mask PO is replaced by the point of the  $I_n$  image. This operation is carried out for all points making up the  $I_n$  image and for all the images of the series from the second image. A comparator C1 shown in Figure 2 performs all of these operations.

[0018] In Figure 3 a determination 2 of the second mask M is carried out relatively similarly to determining the first mask PO. In the first instance, the second mask M is initialised with the first image  $I_n$  of the series of images previously acquired. Then, for each ensuing  $I_n$  image of the series the intensity of the point (i, j) of the image  $I_n$  is compared with the intensity of the corresponding point (i, j) of the second mask M, the point presenting the greatest intensity becoming the new point (i, j) of the second mask M. As before, this operation is performed for all points of the  $I_n$  image and for all the images of the series from the second image.

[0019] On completion of the second stage of the process a determination has been made of a first so-called maximum opacification mask PO at the same time presenting the blood vessels travelled through by the contrast products and the

background structures, with an example of a result thus obtained illustrated in Figure 4. Likewise, the process aiding navigation according to the present invention has determined a second so-called M mask of maximum intensity that shows the sole background structures (an example of which is illustrated in Figure 4).

[0020] In a third stage, generally occurring during surgical intervention on the patient 200 in the region of interest 104, a sequence of live images  $I_L$  is taken in fluoroscopy, while the surgeon inserts an instrument 30 into a blood vessel of the zone of interest 104. Such an image of this sequence is illustrated in Figure 4.

[0021] If the second mask M is subtracted from the live image  $I_L$ , the result is an image representing the instrumentation 30 only; the second mask M allows the background structures of the live  $I_L$  image to be deleted. On the other hand, if the first mask PO of the second mask M is subtracted the result is a vascular cartography/map showing only the set of blood vessels traversed by the contrast product; the elements common to both masks, that is, the background structures, are cancelled out.

[0022] So as to be able to situate instrument 30 the surgeon indicates three coefficients  $\alpha, \gamma, \lambda$  that are actual positives for the process. These coefficients are weighting coefficients vis-à-vis the image representing just the instrumentation ( $I_L - M$ ), just the vascular cartography/map ( $M - PO$ ) and the second mask M, respectively. The weighting coefficients applied to the three images will allow an image  $I_v$  to be visualized which the surgeon can have displayed by the device on means for display 4, in a sub-stage 3. The image  $I_v$  to be visualized is equal to  $\alpha$  times the instrumentation image only plus  $\gamma$  times the vascular map only plus  $\lambda$  times the second mask M. In a variant embodiment the coefficients  $\alpha, \gamma, \lambda$  are actuals of between 0 and 1.

[0023] In another variant embodiment the value of these coefficients can be greater than 1 if the surgeon wants amplification on one or more of the three mages. This addition operation with application of weighting coefficients is performed point by point.

[0024] In a variant embodiment the process does not actually calculate the instrumentation image only, not the vascular map image only. The process directly calculates:

$$I_V = \alpha(I_L - M) + \gamma(M - PO) + \lambda M = \alpha I_L + (\gamma + \lambda - \alpha)M - \gamma PO.$$

[0025] Figure 5 describes a correction stage for images included in a variant embodiment of the process. The set of images  $I_n$  of the series of previously acquired images is not perfect and has noise that has to be corrected. Once the process has determined the first and second masks (PO, M), such as described earlier, the first and second masks are raw and take into consideration all the noise issuing from the series of images at the weakest amplitudes for the first mask and at the strongest amplitudes for the second mask. The average level of the masks thus calculated may be very different from one mask to the other. To correct this spread the process calculates an average intensity  $\bar{m}_L$  that corresponds to the average intensity in the entire region of interest on the series of images, directly from the set of images  $I_n$  of the series of images. Next, the process performs a similar calculation from the previously described first and second raw masks issuing from the second stage. In this way the process determines an average intensity  $\bar{m}_{PO}$  concerning the first mask PO and an average intensity  $\bar{m}_M$  for the second mask PO. Then, using the three calculated average intensity values, the process will correct the abovementioned first and second raw masks PO, M issued from sub-stages 1 and 2. In relation to the first mask PO in a sub-stage 5 the process will re-evaluate the intensity of all the points forming the first raw mask P of equal value  $(\bar{m}_L - \bar{m}_{PO})$  approximately. The result is a corrected first mask PO. Similarly in a sub-stage 6 the process will devalue the intensity of all the points forming the second raw mask M of equal value  $(\bar{m}_M - \bar{m}_L)$  approximately. The result is a corrected second mask M.

[0026] The two masks thus corrected serve as input data for the third abovementioned stage of the process enabling an image  $I_V$  to be visualized to be determined.

[0027] For implementing the entire process it is understood that neither the patient 200 nor the arm 107 is supposed to move between the acquisition of all the images  $I_n$  forming the series of images and the successive recordings at the discretion of the surgeon of live images  $I_L$ . However, if there is movement from either the patient 200 or the arm 107 then the process can automatically impose  $\gamma = 0$  and  $\lambda = 1$ .

[0028] In a variant embodiment of the process the value of the three coefficients  $\alpha, \gamma, \lambda$  live is memorized before displacement in the means for storage contained in the radiography device. Therefore, as soon as the device discovers the previous displacement position the process can again take up the same coefficient values to display the image to be visualized corresponding to this position. This return to the previous displacement position can be done automatically by the radiography device, thus ensuring perfect repositioning, such that the live images  $I_L$  correspond exactly to the set of images  $I_n$  of the series of images initially acquired. All the same, if the surgeon does this return it can be only approximated and the process makes an adjustment to the set of masks PO and M using known image verification techniques by point shift.

[0029] Consequently, the action of calculating a second mask exhibiting only the background structures enables the background structures to be subtracted from the image to be visualised and to have only the cartography/map of the blood vessels be legible by the operator while the instruments are being moved.

[0030] According to other embodiments the process presents at least one of the following characteristics:

[0031] The first mask is determined by:

[0032] initializing the mask with the first image of the series of acquired images;

[0033] for each following image of the series of images the intensity of each point (i, j) of the image of the series is compared to the intensity of the corresponding point (i, j) of the first mask, the least intense point (i, j) becoming the point (i, j) of the first mask.

[0034] The second mask is determined by:

[0035] initializing the second mask with the first image of the series;

[0036] for each following image of the series the intensity of the point (i, j) of the image of the series is compared to the intensity of the corresponding point (i, j) of the second mask, the least intense point (i, j) becoming the point (i, j) of the second mask.

[0037] The image to be determined by a live combination of the first and second masks and of the live image.

[0038] The image to be visualized is determined by a formula of the type  $I_v = \alpha (I_L - M) + \gamma (M - PO) + \lambda M$  where  $\alpha$ ,  $\gamma$  and  $\lambda$  are positive actuals;  $I_L$  is the fluoroscopic image, PO is the first mask, M is the second mask,  $(I_L - M)$  is the image representing the sole instrument and  $(M - PO)$  is the image presenting the map of only the vessels.

[0039] While the masks are being determined the process comprises a process for correcting the noise present in the masks.

[0040] Correction comprises:

[0041] determining an average intensity  $mL$  in a region of interest from the series of images acquired earlier;

[0042] determining the first of raw second masks from the series of images acquired earlier;



[0043] determining an average intensity of the first and second raw masks,  $m_{PO}$  and  $m_M$  respectively, in respective regions of interest corresponding to that of the series of images acquired earlier;

[0044] correction of the first and second raw masks from average intensities  $m_L$ ,  $m_{PO}$ ,  $m_M$  previously evaluated.

[0045] Each point of the first raw mask has an intensity re-evaluated by a value  $(m_L - m_{PO})$  approximately, and each point of the second raw mask has an intensity devaluated by a value  $(m_M - m_L)$  approximately.

[0046] One skilled in the art may make or proposed various modifications to the structure/way and/or function and/or result of the disclosed embodiments and equivalents thereof without departing from the scope and extant of the invention.